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Smart Voice-Based Attendance Management System for Educational Institutions

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Abstract

This is the most important task which needs to be performed within any academic institution, where it manages the attendance of the students. But in the olden days way of managing the students attendance have not only become painstaking but it also has significant loopholes to manipulate the system. The objective of this paper is to eliminate the pitfalls which have long been a part of the conventional means of dealing with students' attendance management, by implementing an innovative solution employ the use of voice recognition technology to automate student attendance management system.

With the output of voice input technology and speech recognition technology, Verified students use a voice-based attendance management system to record their presence in online mode. Technologies used in Voice based attendance management system Java, JavaFX, Python, VOSK and SQLite Technology which makes our Application way more systematic in the backbone of education i.e. Offline and Online classes. The voice-based attendance management system provides efficient student attendance management and reduces the chances of proxy attendance.

KEYWORDS: *Voice Recognition, Speech Recognition, Attendance Management System, Voice Authentication, VOSK, Machine Learning, Educational Technology.*

1. Introduction

Educational institutions need attendance tracking because it helps them monitor student activities and maintain discipline and evaluate student performance. Educational institutions have used manual attendance tracking methods which include paper-based systems and basic digital tracking systems to record student attendance. The systems became inefficient because students used them to attend class through proxy attendance. Traditional student tracking systems have shown their weaknesses because educational institutions now use online and blended learning methods.

The field of speech recognition technology combined with artificial intelligence has achieved substantial progress which now provides better solutions for administrative tasks. The development of voice recognition technology has created an identity tracking solution which can be used in various applications because it demonstrates both accurate performance and secure protection. The system enables identification of people through their distinct vocal patterns without requiring physical contact or the presence of other people. This discovery creates significant effects for both traditional classroom environments and virtual learning settings.

The Voice-Based Attendance Management System will improve current attendance management systems through its voice recognition technology which will produce accurate and timely student attendance records. The system will use speech recognition tools to identify students' voices for attendance verification which will be stored in a database. The proposed attendance management system will achieve high efficiency and accuracy and security through its implementation of Java and JavaFX and Python and VOSK and SQLite technology.

The research aims to develop an attendance management system that operates with high efficiency while maintaining user-friendliness and requiring minimal human intervention for attendance recording and solving the issue of attendance registration fraud and enabling students to attend their classes through both online and offline methods. The proposed attendance management system will be a significant contribution to the digital transformation of the education sector by providing a smarter way of recording attendance.

2. Related work

Research has also been carried out on automated attendance systems using various technologies to ensure accuracy and efficiency in attendance recording. Some conventional methods include using RFID technology-based attendance systems, whereby students are required to carry RFID tags that are scanned on arrival in class. Although this method minimizes human interference in the system, it is prone to abuse by students whereby multiple students use a single tag.

With the advent of technology in the form of biometric technology, researchers have also focused on the use of authentic and secure identification technologies in the development of automated attendance recording systems. Fingerprint recognition system-based attendance recording systems and face recognition system-based attendance recording systems have gained popularity in recent years. Hence, several studies have been conducted on the use of these technologies in the development of automated attendance recording systems. Fingerprint recognition system is unique in terms of identifying an individual. However, there are also some issues related to the cleanliness of fingerprint recognition sensors. Face recognition system is also unique in terms of identifying an individual. However, there are also some issues related to lighting conditions and accuracy in real-time calculations.

Voice recognition has also received research attention as a viable biometric system owing to its non-intrusive and interactive nature. Research in voice recognition systems has used cloud-based API services for speech recognition and pattern matching, and deep learning techniques for the

identification of unique voice features for identification purposes. However, these systems are limited in their functionality owing to the requirement for network connectivity and the privacy implications associated with the use of cloud services. Moreover, there is a lack of research in voice recognition systems for the entire range of online and offline learning scenarios.

However, recent advancements in offline-based frameworks for speech recognition systems have enabled the creation of robust systems that are independent of network connectivity for functionality. Tools such as VOSK are effective in the creation of robust speech recognition systems.

However, there is a lack of literature that incorporates the use of voice recognition as well as the entire attendance management system that can work effectively in an online and offline environment. The aim of the study was to bridge the gap that had been created in the literature regarding the use of voice recognition as well as a user-friendly interface and effective management of the database. The above is an advancement of the literature since it attempts to offer a solution to the problem.

3. Research Methodology

The development of Voice-Based Attendance Management System has been carried out by following a systematic approach in order to ensure the accuracy, reliability, and usability of the system. The methodology followed for the development of the system is as follows:

1. Requirement Analysis

The first step in the methodology followed for the development of the system is to identify the drawbacks of the system and the requirements. The important aspects of the requirement analysis phase were as follows:

- To automate the attendance recording system
- To ensure the security of the identity verification system
- To allow the system to be used for both offline and online classes
- To minimize the involvement of humans in the system and the chances of fraud in attendance

2. System Design

It is proposed that the system design would be modular in nature by dividing the system into different modules. These would be:

- User Interface Module
- Voice Capture and Processing Module
- Voice Recognition Module
- Database Management Module

Java and JavaFX have been used for developing an interactive graphical interface through which students' registration, login, and attendance marking may be carried out. It is proposed that different modules of the system would interact with each other.

3. Voice Processing and Recognition

The major part of the proposed system would be the voice recognition. The methodology followed in the proposed system would be:

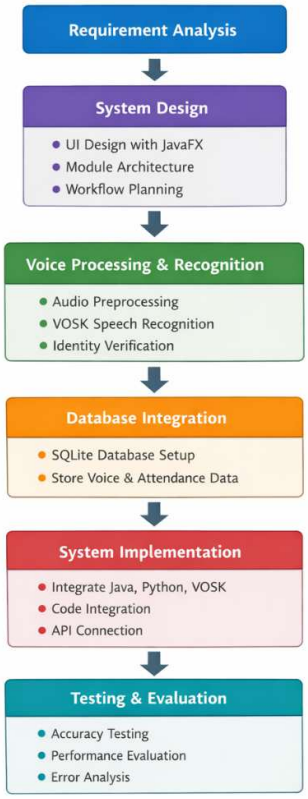
- Capture the voice using the microphone
- Pre-processing of the audio signals
- Identifying the features of the voice
- Identifying the captured voice with the stored voice

The programming language used in the proposed system would be Python with the help of the VOSK toolkit.

The proposed system would be used to verify the identity of the students based on the pattern of the voice before marking the attendance.

3.1. Overall Methodological Framework

The overall workflow of the proposed system is shown below.



3.2. Dataset Collection

The performance of the Voice-Based Attendance Management System is highly dependent on the quality and characteristics of the voice dataset used for voice recognition and verification. For the purpose of this project, a separate voice dataset has been created for accurate speaker identification and for the efficient implementation of the system.

1. Data Source

As the focus of this project is to identify individual students and not perform speech recognition in general, voice samples are collected directly from the users of the system. Each student is asked to record a few predefined phrases like their name, roll numbers, or a fixed sentence like “Present Sir/Madam.” This helps in maintaining uniformity in the collected voice dataset and allows for the identification of unique voice characteristics.

2. Data Collection Process

- For the purpose of voice recognition, voice samples are collected using a standard microphone.
- Multiple voice samples (5-10 recordings) are collected

from each student for accurate voice recognition purposes.

- Recordings are collected in different environments (quiet classroom and mild background noise) for efficient system performance.

3. Preprocessing

- The audio data also went through certain preprocessing steps before being fed into the system:
- Noise Reduction
- Normalization of audio levels
- Removal of silent audio segments
- Conversion to required sampling rate, which is also supported by VOSK
- These steps also helped in better clarity and accuracy.

4. Dataset Storage

The voice samples are stored locally. The voice samples are related to the corresponding data of students stored in the SQLite database.

- For each student, the data stored is as follows:
- Student ID
- Name
- The related voice sample
- A timestamp is stored for each student during the registration process
- This is also useful for data management

5. Dataset Size

The dataset size is related to the voice samples provided by students who are already registered in the system.

Since students provide more than one voice sample, it is enough to test the voice verification system in real-time.

6. Privacy and Ethical Considerations

The students were made aware that voice samples were being collected from them. The voice samples that were collected from the students were only for verification purposes.

The third-party service was not used, as it was an offline speech recognition.

3.4. Model Development

The fundamental concept of the proposed Voice-Based Attendance Management System is the voice recognition/verification model, which has been developed with the aim of recognizing/verifying the input voice provided by students in an efficient and effective manner.

1) Model Selection

Instead of designing and developing a speech recognition model, the offline speech recognition framework, i.e., VOSK, has been chosen due to its light design and the facility it offers to process the speech in real-time without the need to be connected to the internet.

The main focus of the system is speaker recognition and speech recognition, in which the speech is recognized and compared with the information provided by the users in order to identify the person attending.

2) Audio Input and Features Extraction

The designing of the voice recognition and verification system starts from the point of time when the audio input is taken from the microphone.

The audio input is preprocessed for:

- Filter the audio from any unwanted sounds
- Normalize the amplitude
- Adjust the sampling rate

During the processing phase, the distinctive voice features that represent the unique voice characteristics of the students are extracted.

3) Integration of the Speech Recognition System

The VOSK engine will be used to recognize the preprocessed sound signal. The speech signal will be recognized in real time and matched with the data that has already been available in the database. The data that has already been available in the database will be related to the students, i.e., the name and the roll numbers of the students.

The speech will be matched with the data that has already been available in the register. If it matches the data that has already been available in the register and also matches the identity, then the attendance will be marked.

4. Identity Verification Logic

- The identity verification mechanism is as follows:
- Collect the voice input
- Convert the voice into text using the VOSK engine
- Compare the text with the stored data
- Verify the identity of the students
- Record the attendance in the SQLite database along with the timestamp

This logical mechanism is implemented in the system so that the attendance is recorded only for the students who are identified.

5. Model Optimization

To optimize the model:

- Multiple voice samples were collected for the students
- Testing was done in various environmental conditions
- Error handling was done
- Latency was optimized in the system

6. System Integration

The final model has been integrated with the following:

- Java for application logic
- JavaFX for graphical user interface
- Python for audio processing
- SQLite for secure data storage

The model has been useful in efficient communication regarding the working of the system.

3.5. Model Training

The training phase of the Voice-Based Attendance Management System is for the preparation of the system for proper voice recognition and verification of the students' voice inputs. Since the system is based on the VOSK offline

speech recognition toolkit, the focus is not for the development of a deep learning model.

1. Pre-trained Model Utilization

The VOSK toolkit provides a pre-trained model. It has the capability to translate the words that are spoken by the user into text. It is a pre-trained model that has the capability to efficiently recognize the words that are spoken by the user. In the proposed system, the pre-trained model is utilized in the system. It is utilized in the speech recognition process without the internet connection.

2. Speaker Enrollment (User Training Phase)

Although the speech recognition engine is pre-trained, there is a need for the user training phase, in which the students are enrolled.

- Multiple voice samples were taken for each student (5-10 recordings).
- A specific phrase was used for all students for consistency.
- The recordings were taken in slightly different environmental conditions.
- The audio samples were stored and correlated with the corresponding student ID in the database.

This phase was the user training phase for the system.

3. Data Preparation

The audio samples collected were converted to the desired format. After the collected data was successfully converted, the collected audio samples were ready for verification. The process of conversion of the collected audio samples was as follows:

The collected audio samples were converted to the desired sampling rate format. The collected audio samples were cleaned up. The collected audio samples were normalized.

4. Matching and Validation Mechanism

- During the marking of attendance:
- The system records the voice input.
- The speech is converted into text by the VOSK model.
- The speech is compared with the records of the students.
- If the speech is found correct, the attendance is marked.
- The above mechanism is the operational learning mechanism.

5. Performance Tuning

The system is tested multiple times to improve the performance of the system. The changes are made based on the following parameters:

- Recognition accuracy
- False acceptance cases
- Response time
- Handling environmental noises

By enhancing preprocessing techniques and supplying enough voice samples, the reliability of the system is enhanced.

3.7. Model Evaluation Strategy

The evaluation of Voice Based Attendance Management System has been carried out to test the accuracy, reliability, and robustness of the system. Since it is a speech recognition system, it has been evaluated according to the accuracy of speech recognition and efficiency of the system.

1. Evaluation Objectives

- The objectives of the model evaluation are as follows:
- To test the accuracy of voice recognition
- To test the reliability of identity verification
- To test the response time of the system
- To test the response of the system under different environmental conditions

2. Testing Environment

The system is tested under offline classroom environments as well as online meeting room environments.

In quiet, moderately noisy, and noisy surroundings, voice recognition is performed in order to assess the system's response in different environmental conditions.

3. Performance Metrics

The following metrics were used to evaluate system performance:

a) Recognition Accuracy

Accuracy was calculated as:

$$Accuracy = \frac{Number\ of\ Correct\ Identifications}{Total\ Number\ of\ Attempts} \times 100$$

This measure was used to find the rate at which the system recognized and verified a student.

b) False Acceptance Rate (FAR)

The percentage of false cases in which the system incorrectly marked the attendance of an unauthorized voice.

c) False Rejection Rate (FRR)

The percentage of false cases in which the system failed to recognize a registered student.

d) Response Time

The time taken between the input of voice samples and the recording of attendance in the database. Real-time processing was considered satisfactory if completed in a matter of a few seconds.

4. Test Procedure

Registration of multiple students with voice samples.

Multiple tests of attendance for each student.

Variations introduced: change of tone, background sounds added.

Correct and incorrect identification.

5. Result Analysis

The system was found to be accurate in a quiet environment. But the system was found to be stable in a moderately noisy environment. False acceptance was found to be low due to the identity verification logic. False rejection was also found to be low due to the use of multiple voice samples collected from the students.

6. System Reliability

The reliability of the system was checked by performing multiple trials on the system. The stability of the system for

database logging was found to be good by integrating Java, Python, VOSK, and SQLite. The offline speech recognition facility ensured the privacy of the users.

3.8. Deployment Methodology

The deployment of Voice Based Attendance Management System has been carried out with the aim of ensuring that the deployment and operation of the system are done in a real-world scenario.

1. Deployment Environment
The system has been developed in a way that it could be deployed on any normal computer or laptop without the need to meet any specific requirement for the installation of any high-end hardware.

The minimum deployment requirements that are required by the system are as follows:

- A computer with JRE (Java Runtime Environment) installed.
- A Python environment with required libraries installed.
- A microphone for the purpose of taking voice input from users.
- SQLite database support is required.

The deployment of the system can be done without any need to connect it with the internet because the system makes use of an offline speech recognition engine, i.e., VOSK.

2. Software Configuration
The following activities were carried out before the deployment of the Voice-Based Attendance Management System:

- Installation of the Java and JavaFX SDKs.
- Installation of the Python SDK.
- Integration of the VOSK speech recognition engine with the project directory.
- Configuration of the SQLite database.

All the dependencies were ensured to be in place to enable proper communication between the Java and Python environments.

3. System Integration
The system deployment process needed the following systems integrated:

- Java and JavaFX for the frontend and system logic, respectively
- Python scripts for voice processing
- VOSK for speech recognition
- SQLite for data storage

The inter-process communication was set up to facilitate real-time data exchange between the Java and Python processes.

4. Installation Process
The system was developed as a desktop application. The system deployment steps are as follows:

- Setting up the project files
- Setting up the database location
- Verifying the functionality of the microphone
- Running system checks

Finally, the administrator's login credentials are set up for managing students' registrations and attendance.

5. User Setup and Enrollment
The information regarding the students was entered into the system through its interface after deploying the system. This was an important aspect to be considered while setting up the system to mark the students' attendance in real time.

6. Testing After Deployment
The system that was deployed was tested to ensure that certain requirements were met. These requirements were as follows:

- The voice recognition was accurate
- The database was correctly logged
- The attendance was marked in real time
- The system was stable for frequent use

The system was said to be deployed successfully if it marked the students' attendance correctly without any errors.

Conclusion and Future work
The proposed Voice-Based Attendance Management System has been developed with the aim of overcoming the disadvantages of existing methods of attendance, such as human errors, time consumption, and proxy attendance. The proposed system has been developed using voice recognition technology and database technology, which will help in providing a secure and efficient method of student attendance.

The proposed system has been successfully able to incorporate Java, JavaFX, Python, VOSK, and SQLite technologies for developing a user-friendly and efficient application for offline and online environments. The offline speech recognition technology will be able to provide better security and freedom from internet connectivity for better performance. The results of the proposed system have shown better accuracy in a normal classroom environment with a consistent response and data logging.

The project has been able to prove the feasibility of using voice-based biometric technology as an alternative to the conventional and other biometric-based student attendance systems. The project has been able to make a significant contribution to the digital revolution in educational institutions by providing them with a smarter and more efficient means of student attendance management without any physical contact.

Though the project is working fine, there are a few areas of improvement that can be incorporated in the project to increase the efficiency of the project:

- Advanced Speaker Recognition:** The project may be improved by using deep learning techniques for speaker verification.
- Cloud-Based System:** The project may be implemented by using cloud technology.
- Integration with Mobile Apps:** The system may be made compatible with mobile apps, making it a user-friendly system.

- Multi-Factor Authentication:** The system may be made more efficient by using multiple factors for authentication, including facial recognition or One-Time Password.
- Improved Handling of Noise:** The system may be made more efficient by using improved noise-reducing techniques, making it a more effective system for the classroom setting despite the presence of noise.
- Analytics and Reporting Module:** An analytics module may be incorporated into the system, enabling the faculty members to analyze the trends in attendance.

All these features may be incorporated into the system, making it a better, efficient, and intelligent attendance management system.

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